Today's plan:

Correction for the final presentation dates!

Using data sheets

Powering your project

Op-Amps

Announcements: Final Reports and presentations

At the end of the course you'll present your project in two ways:

1) Oral presentation in class. These will happen on Tuesday April 1, Wednesday April 2 and Thursday April 3. These are reasonably informal. We will all look at the presentation, with slides if any, and the working project.

2) Formal written report, due April 11th, 10PM.

Unfortunately no extensions! Exams start on 12th

Announcements: Status Report

I would like a short written status report from everyone turned in at start of the lab during the week of March 24th.

The report should discuss your progress so far: what has been accomplished, what remains to be done. If you have encountered problems, discuss them, and your plans to move forward. If you need help to make progress, please mention it.

These reports need not be long, just a few sentences or points are fine.

Project is yours!

Find the info you need on line, use AI, discuss with colleagues but do not expect TA, a friend or me to do it for you!

We can help with errors in the code but can not provide example codes or “how to” instructions.

Printing is available for reasonable small items in the next room with the help of Bernhard our make room instructor, but you have to prepare the file.

A word about data sheets

- Beware of sections entitled "Absolute Maximum Ratings"
- These sections tell you about the most extreme conditions the component can be subjected to without being destroyed. These conditions are usually very far away from the optimal operating conditions! To find suitable operating conditions, there is often a table of Electrical Parameters – look for the conditions under which other parameters are measured.

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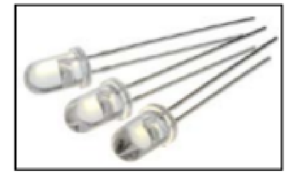
LED1200-series



TECHNICAL DATA

Infrared LED InGaAsP

LED1200-series are InGaAsP LEDs mounted on a lead frame and encapsulated in various types of epoxy lens, which offers different design settings.
On forward bias, it emits a high power radiation of typical 5 mW at a peak wavelength at 1200 nm.

Specifications

- Structure: InGaAsP
- Peak Wavelength: typ. 1200 nm
- Optical Ouput Power: typ. 5 mW
- Resin Material: Epoxy resin
- Solder: Lead free

Absolute Maximum Ratings (T_a=25°C)

Type	Symbol	Value	Unit
Power Dissipation	P_D	140	mW
Forward Current	I_F	100	mA
Pulse Forward Current	I_{FP}	1000	mA
Reverse Voltage	V_R	5	V
Operating Temperature	T_{OP}	-40 … +85	°C
Storage Temperature	T_{STG}	-40 … +100	°C
Soldering Temperature (for 5 sec.)	T_{SOL}	265	°C

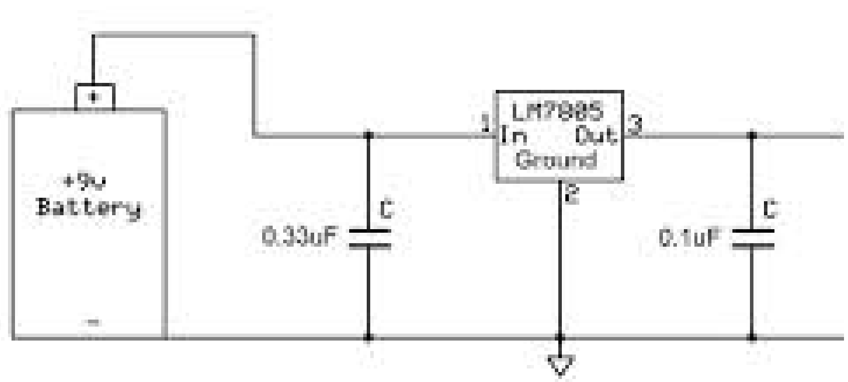
Electro-Optical Characteristics (T_a=25°C)

Item	Symbol	Condition	Min.	Typ.	Max.	Unit
Forward Voltage	V_F	I_F = 50 mA	-	1.1	1.5	V
Reverse Current	I_R	V_R = 5 V	-	-	10	µA
Radiated Power	P_O	I_F = 50 mA	3	5	-	mW
Peak Wavelength	λ_P	I_F = 50 mA	1150	1200	1250	nm
Half Width	$\Delta\lambda$	I_F = 50 mA	-	80	-	nm
Rise Time	t_r	I_F = 50 mA	-	10	-	ns
Fall Time	t_f	I_F = 50 mA	-	10	-	ns

Voltage Regulation

- To power the Launchpad and most other circuitry, you'll want to use a regulated voltage. 3.3 V for the Launchpad, maybe 3.3V or 5V or 15V for other components. (one can run MSP430 off of 2 AA or AAA batteries directly).
- These voltages are most easily made with a 3 pin voltage regulator.
- eg LM7805, LM7815, UA78M33

- These can supply up to 1A, but may need a heatsink
- Notice that the values of the 2 capacitors are indicating just an order of magnitude! 1μF will work for both.

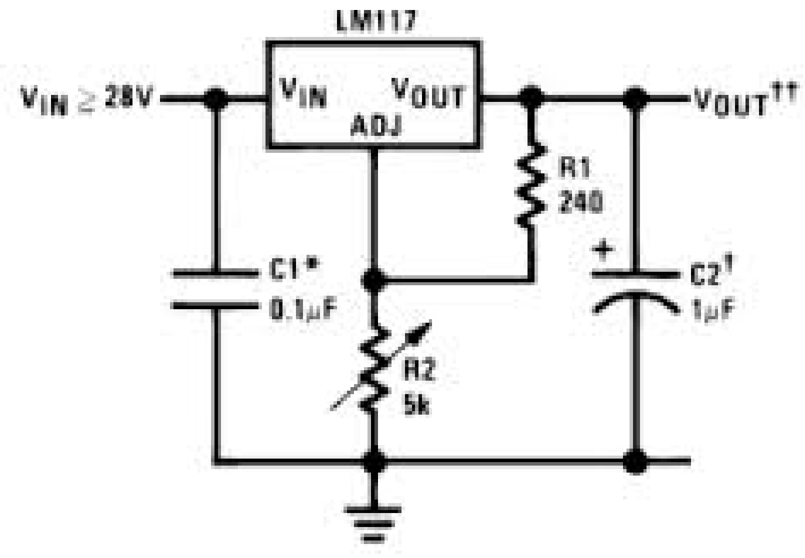


To 5V pin on Launchpad

To ground pin on Launchpad

Voltage Regulation

For 'non-standard' voltage, LM317 is a three-terminal, adjustable regulator



The regulator attempts to maintain:
$V_O - V_{ADJ} = 1.25$ V (Vref)

So V_{out} is set by the ratio of R_1/R_2

$V_O = V_{REF}\,(1 + R_2/R_1) + I_{ADJ}\,R_2$
$I_{ADJ} = \sim 50$uA.

Choose R_1, R_2 so that I_{ADJ} x R_2 is small, but also so V_O x (R_1+R_2) is not big.
$R_1 = 240\ \Omega$ is recommended.

Power dissipation

- Three pin regulators can get very hot, and may need a heatsink. They tend to draw exactly the same current from the supply as they output, and they dissipate the power difference.

For example, a 5V regulator operating from a 12V supply, supplying 1A has to dissipate (12V-5V)x1A = 7W. Without a heatsink, this would get very hot, very fast!

Dropout

- Many 3 pin regulators have a fairly high (1.5 – 2 V) “dropout” voltage. This means that for a 5V regulator, the input needs to stay above 6.5-7V. It will not work from 4 AA batteries!
- There exist “low-dropout” regulators, some of which are also low-power. LP2950 is a nice family.

Powering your project

Easiest, if it works:

- Launchpad from your computer
- the board/external circuitry with the wall wart we've provided.
- any higher current devices (eg big motors) from the batteries or a power supply available in the lab.

Powering your project

For mobile platforms or other devices:

- Launchpad and control electronics from
- Power researchable bank, if not,
- 9 V battery and 5 V regulator.
- Higher current devices (motors, electromagnets) from the batteries.

DC power supplies

- DC supplies come in two general flavours:
- Switching and Linear

- The difference between these is in the internal structure of the supply. Switching supplies tend to be smaller/lighter/cheaper/more efficient than linear, but can introduce noise (10's to 100's of kHz).

Wall Warts or Bricks

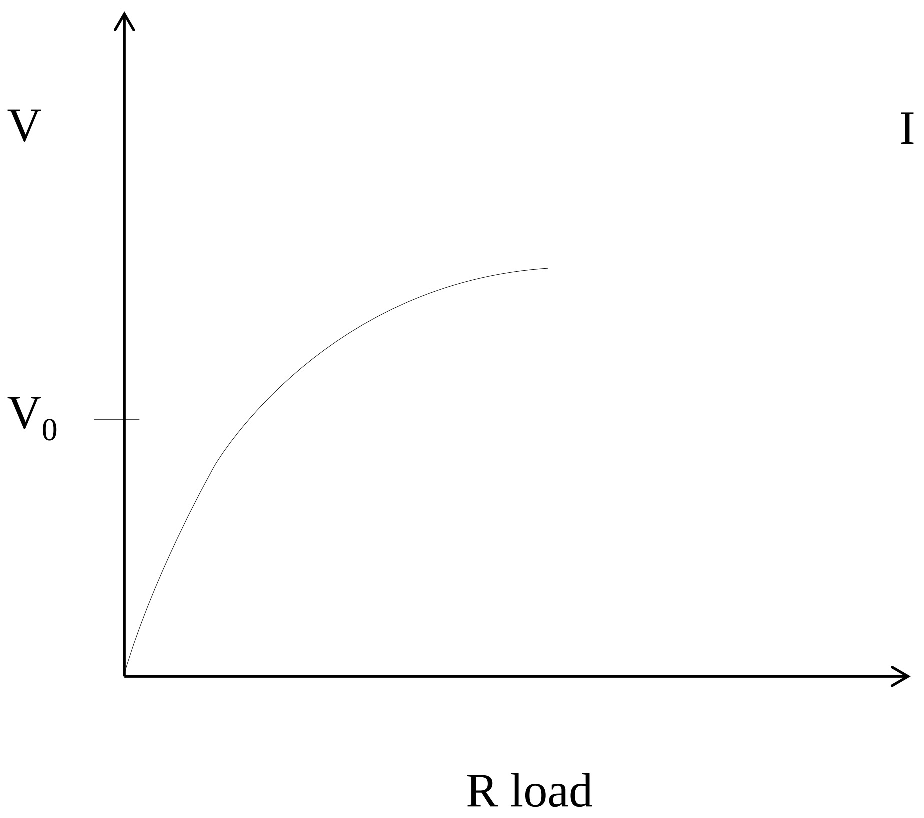
Most wall warts sold with consumer electronics are DC, switching, unregulated.

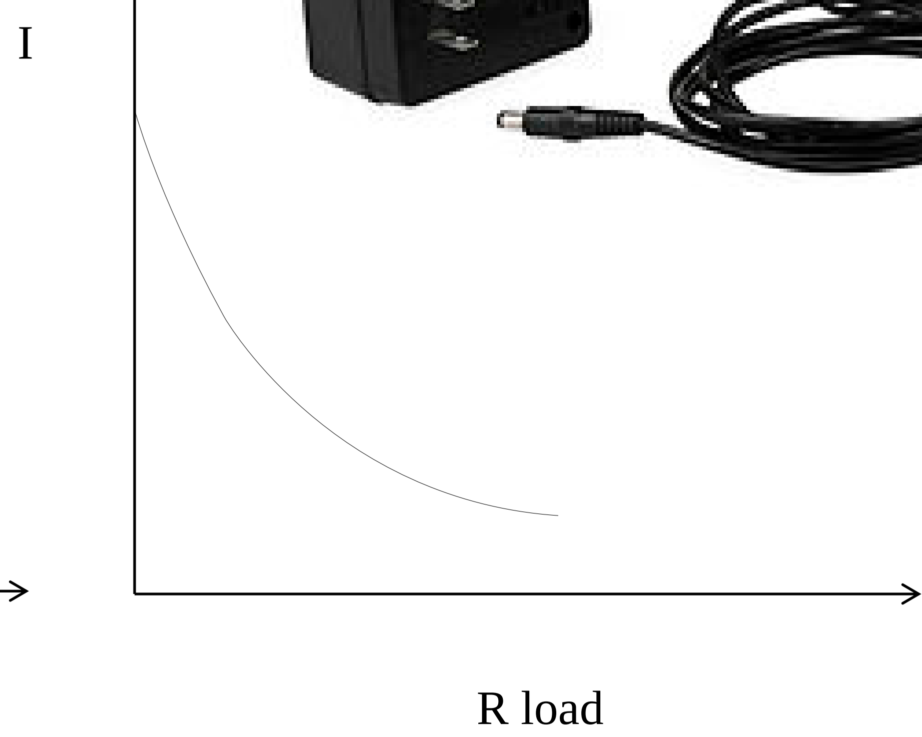
The voltage only matches the specified output voltage when the current draw is near to the specified current capability. Lower current draw yields higher voltage, may be as much as twice the specified voltage!

For driving motors, that may be ok, but for powering logic or amplifier circuits, you'll need to regulate wall wart outputs

Wall Warts

For most unregulated wall warts, voltage and current graphs look like these:





Wall Warts

Wall warts can be DC or AC, and regulated or not. Often we have to test them to find out.

Newer wall warts with USB connections are regulated at 5V

Batteries

Many sizes/shapes/chemistries:

Lead-acid - commonly available in 6V/12V. High power. Heavy, rechargeable.

Lithium. Rechargeable or not. Rechargeables are a little tricky to use – must not overcharge or undercharge. Light weight.

alkaline (AA and friends)

Ni-MH/NiCd – easiest rechargeables to use but rare now. Memory issue

coin cells/specialty (eg PX28L 6V camera battery)

Batteries

For most battery chemistries, the voltage changes as the battery is discharged. Eg alkalines start off ~ 1.5V, but discharge to ~ 1.0V.

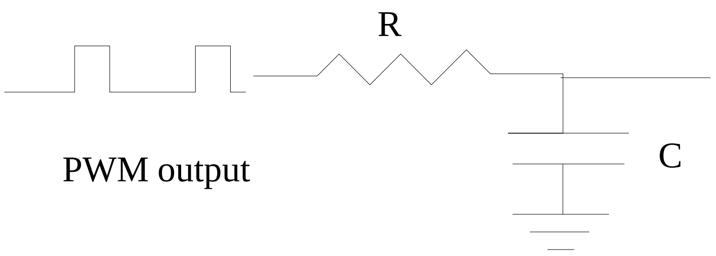
Many batteries can supply very high peak current – A fresh D battery can supply ~ 10A for a short period! Lead acid batteries can supply 100's of A. Due respect is required. Short circuit protection and possibly reverse connection protection should be considered.

Like most other electronic components, batteries have data sheets with lots of useful information on them!

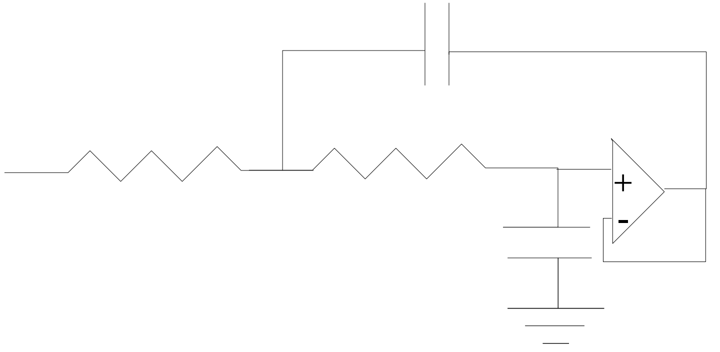
Analog Output:

The MSP430F5529 doesn't have a DAC. If you want an adjustable analog output, there are a couple of options:

- Add an external DAC (serial or parallel)
- low-pass filter and PWM output.



PWM output



2nd order Low-pass filter

Analog Output:

Parallel DAC: eg TLC7528, Dual 8bit multiplying digital to analog converter.

TLC7528C, TLC7528E, TLC7528I
DUAL 8-BIT MULTIPLYING
DIGITAL-TO-ANALOG CONVERTERS

SLAS062E – JANUARY 1987 – REVISED NOVEMBER 2008

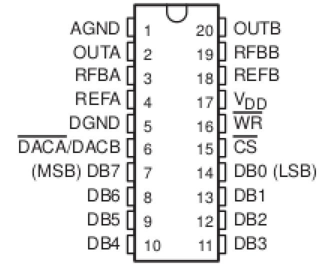
- **Easily Interfaced to Microprocessors**
- **On-Chip Data Latches**
- **Monotonic Over the Entire A/D Conversion Range**
- **Interchangeable With Analog Devices AD7528 and PMI PM-7528**
- **Fast Control Signaling for Digital Signal Processor (DSP) Applications Including Interface With TMS320**
- **Voltage-Mode Operation**
- **CMOS Technology**

KEY PERFORMANCE SPECIFICATIONS	
Resolution	8 bits
Linearity Error	1/2LSB
Power Dissipation at V_{DD} = 5V	20mW
Settling Time at V_{DD} = 5V	100ns
Propagation Delay Time at V_{DD} = 5V	80ns

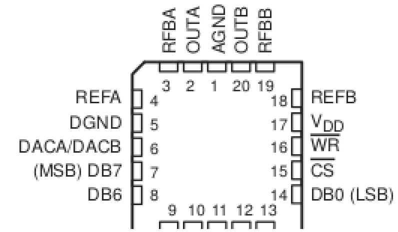
description

The TLC7528C, TLC7528E, and TLC7528I are dual, 8-bit, digital-to-analog converters (DACs) designed with separate on-chip data latches and feature exceptionally close DAC-to-DAC matching. Data are transferred to either of the two DAC

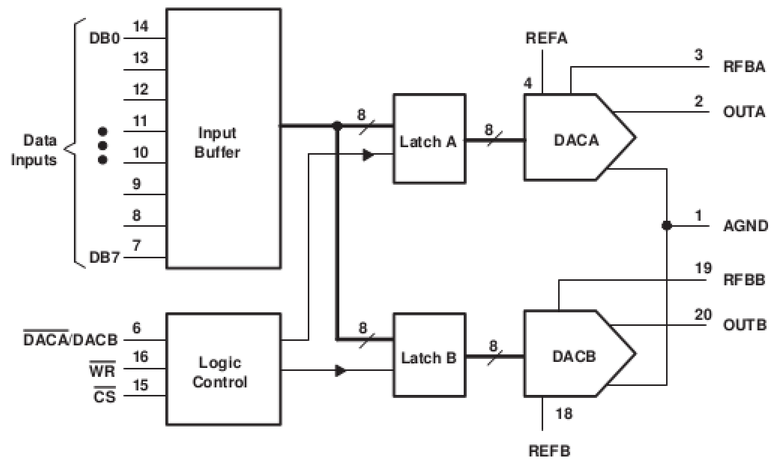
DW, N OR PW PACKAGE
(TOP VIEW)



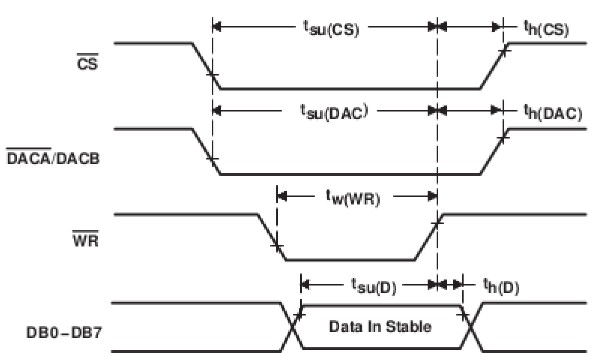
FN PACKAGE
(TOP VIEW)



DAC: TLC7528

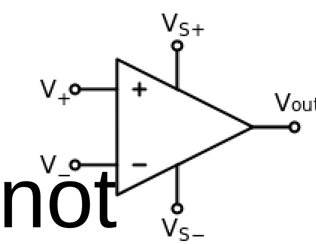


operating sequence



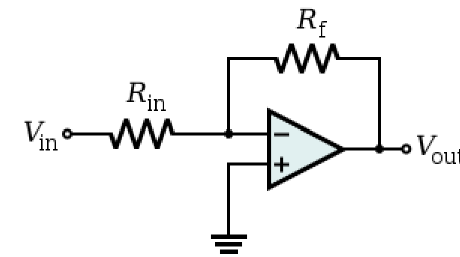
Op-amps

- Vout = A (V_+-V_-), where A is a large number (10^4-10^6)
- Exact value of A is usually not very important.
- (Almost) always use in a circuit with feedback.



- Needs power supplies, often not shown on circuit diagrams. Typical supplies are +/- 15V, but can vary.

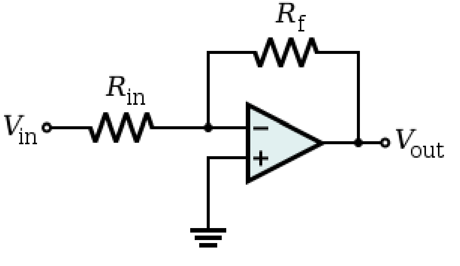
Golden Rules



- (1) The output attempts to do whatever is necessary to make the voltage difference between the inputs zero.
- (2) The inputs draw no current.
- Both rules are approximations! Rule (1) is only obeyed in a circuit with negative feedback, and the difference is usually not quite 0. The inputs draw a tiny amount of current.

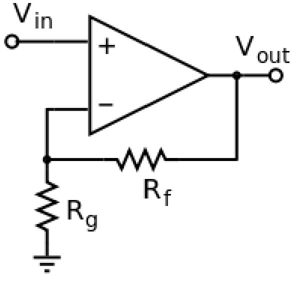
Inverting amplifier

- $V_{out} = -V_{in}\, R_f/R_{in}$
- Often the preferred topology, except:
- Low-ish input impedance (R_{in})



Non-inverting amplifier

- $V_{out} = V_{in} (1 + R_f / R_g)$
- input impedance limited by the op-amp itself (usually very high!)



Imperfections

- Gain, A, is not frequency independent. The op-amp gain will roll off at high frequency (design choice for stability).
- inputs do draw some current (input bias current) – must provide a dc current path!
- Output cannot swing beyond (or in some cases even too close to) the power supply rails.

Single supply amplifier

- When working with microcontrollers it is often convenient to have an amplifier that can be powered from 0/5V or 0/3.3V rather than +/-15V.
- Previous circuits need some modifications: (a) need to reference inputs from the supply midpoint. (b) often want to AC couple the input.
- TI has some nice documents:

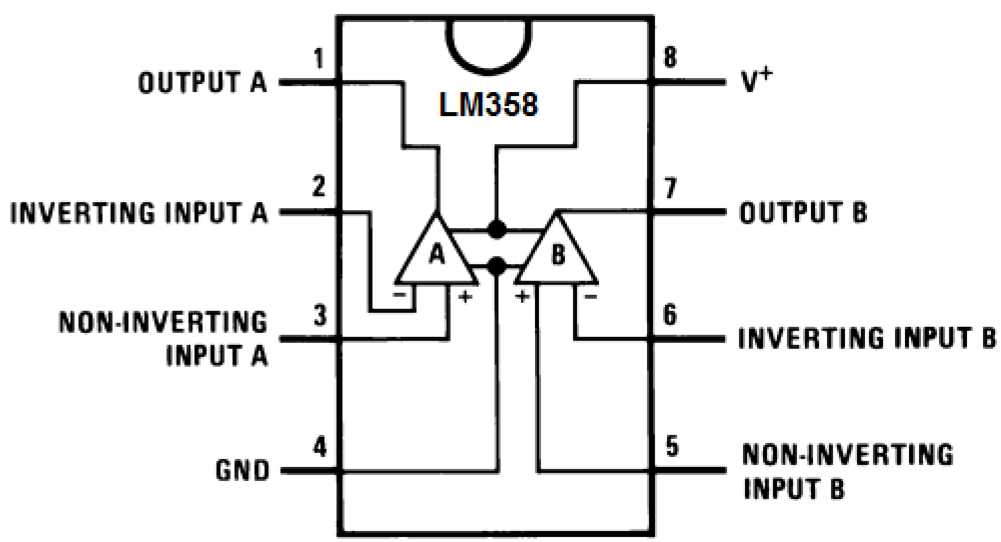
https://courses.cit.cornell.edu/bionb440/datasheets/SingleSupply.pdf

www.ti.com/lit/ml/sloa091/sloa091.pdf

www.ti.com/lit/an/sloa030a/sloa030a.pdf

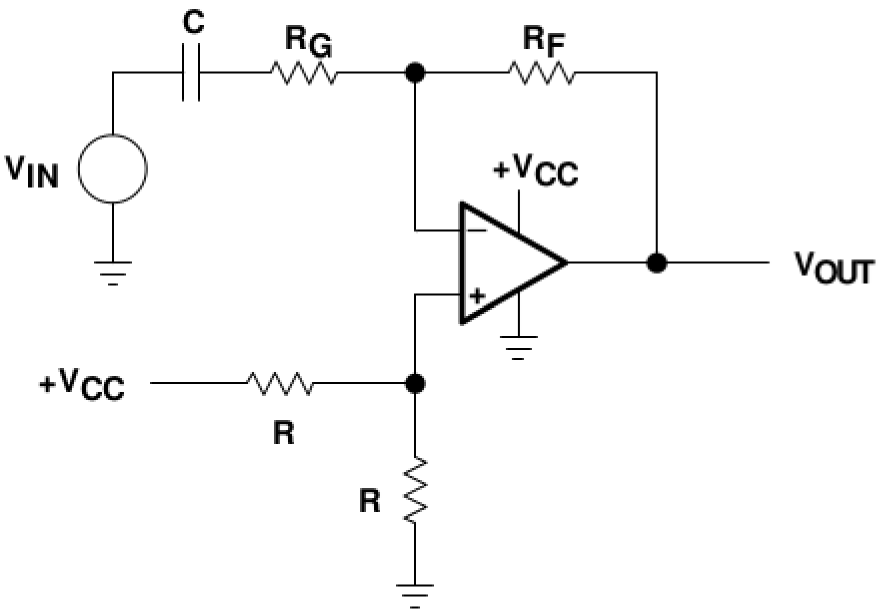
Single supply amplifier

- LM358. Dual, single supply.
- V+ = 5V (pin 8), V- = 0V (pin 4).
- Outputs can swing from ~0 V to ~ 3.5 V.



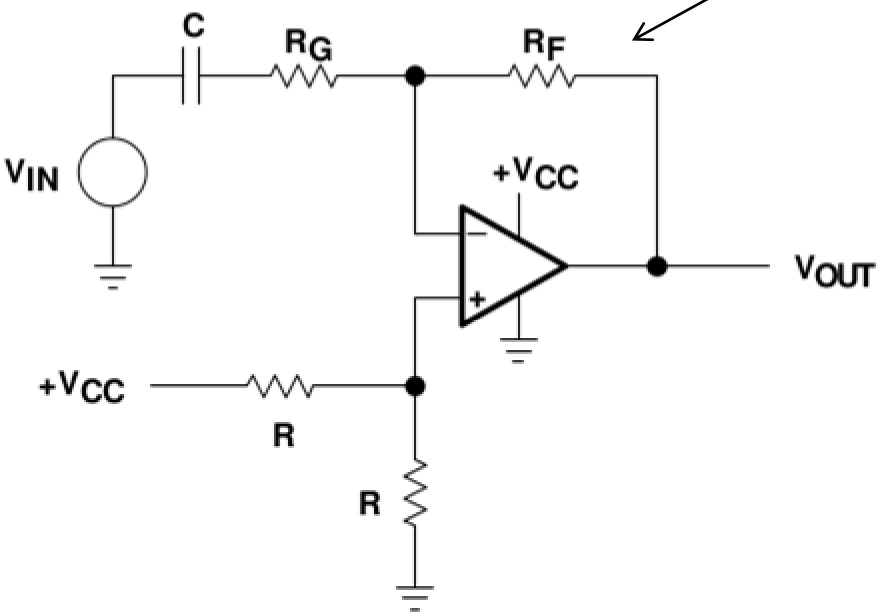
Inverting AC amplifier:

Gain = R_F/R_G



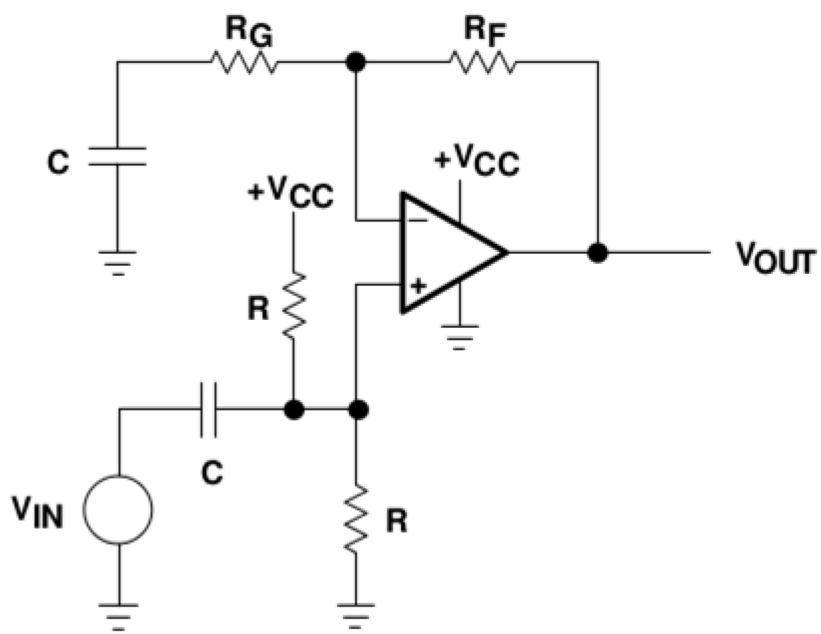
Inverting AC amplifier:

add a capacitor
in parallel with R_F
to get a low-pass filter



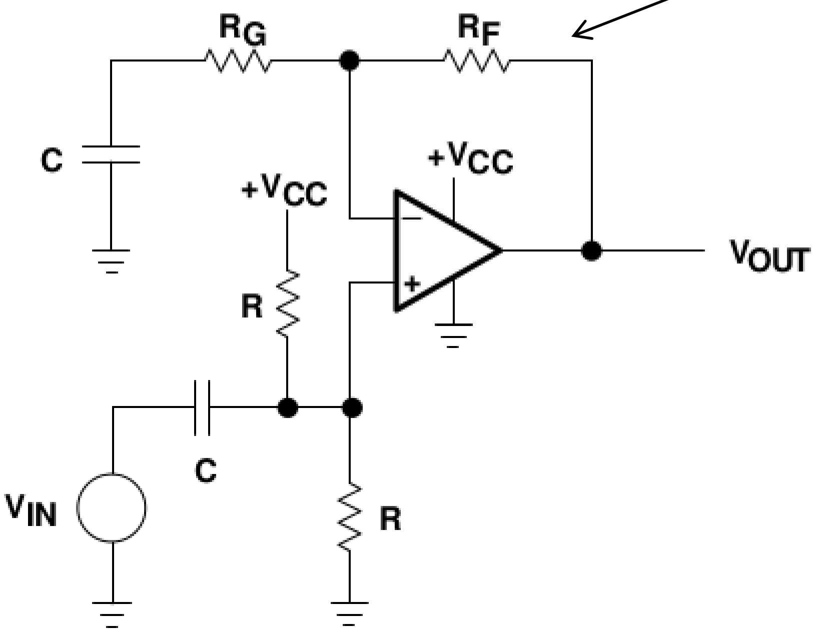
A non-inverting amplifier:

Gain = $1+R_F/R_G$



A non-inverting amplifier:

add a capacitor
in parallel with R_F
to obtain a low-pass fil



2^{nd} order filters:

LOW PASS

Unity Gain
Butterworth
R3 = R4 (HIGH)
R1 = R2
C1 = 2C2
Fo = $\sqrt{2}$ / (4π R1C2)

HIGH PASS

Unity Gain
Butterworth
C1 = C2
R1 = R
R = 2R1
Fo = $\sqrt{2}$ / (4π R1C1)

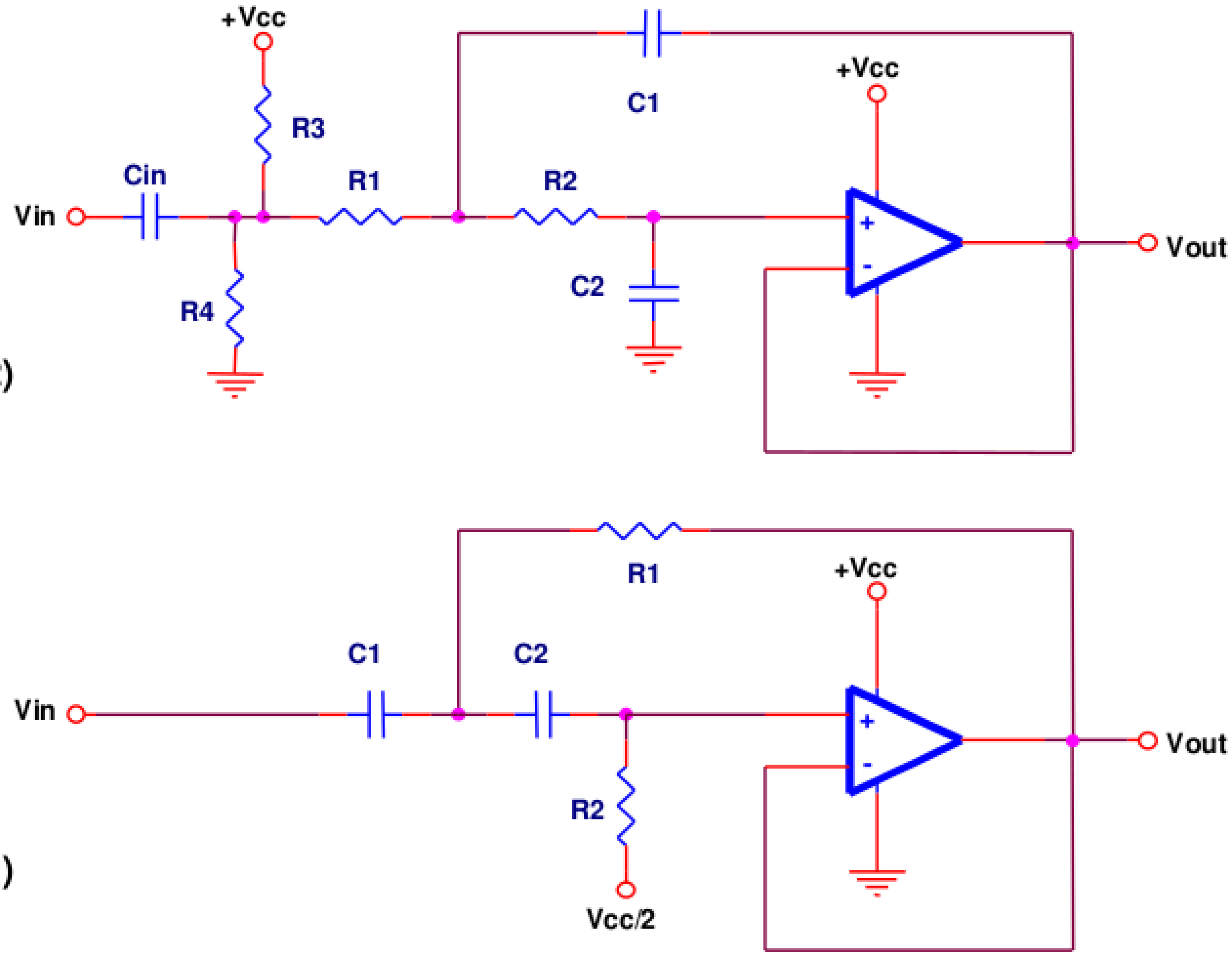
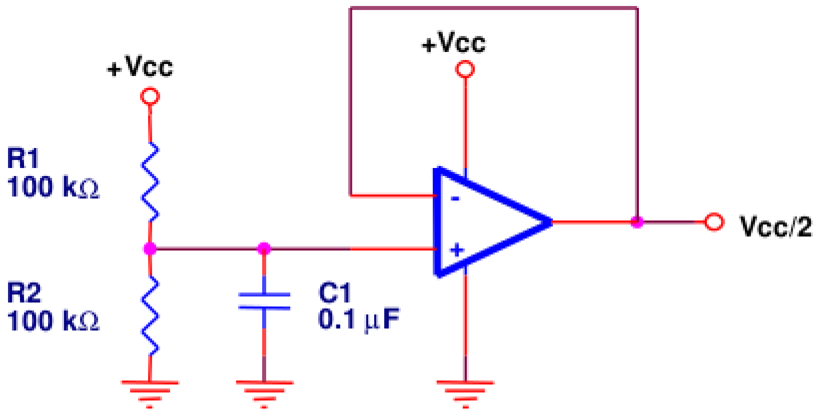


Figure 16. Sallen-Key Low- and High-Pass Filter Topologies

If you need to generate stable Vcc/2 (which is the op-amp “ground”) use a second op-amp:



If you need to generate Vcc/3 use a second op-amp:

If Vcc = 5V,
make R_1=200k, R_2= 100k,
puts output at:
1.67 V.